U S D A FOREST SERVICE
RESEARCH NOTE RM-223

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Prediction of Air Temperature at a Remote Site from Official Weather Station Records

Ralph E. Campbell[1]

Air temperatures at the San Luis experimental watershed were predicted from temperatures at Albuquerque, New Mexico, on the basis of linear regressions between temperatures at the two locations calculated from a full year of continuous record at San Luis and official 3-hour records at Albuquerque. Hourly temperatures were predicted within ±6.3° to 7.8° F., depending on time of day. Predictions of daily mean temperatures at San Luis were within ±3.8° F. Monthly mean temperatures for a given time of day were predicted within ±3.6° to 5.5° F.

Keywords: Temperature forecasting, air temperature, weather patterns.

The air temperature at the local weather station is readily available. But to find the temperature at a site 60 miles away and 10 miles off the highway over rough country is much more difficult, particularly immediately after a thunderstorm in summer or a snowstorm in winter.

If the remote site is at similar elevation and is subject to weather patterns similar to those at the local weather station, temperature at the site may be estimated from local data (Thom 1968). A rancher, land manager, or research scientist may need this information.

How closely may he estimate the temperature at the remote site? The value of the estimate depends on the precision with which it is made. We continuously recorded the temperature for 1 year at the San Luis experimental watershed, which lies 60 air miles from Albuquerque, New Mexico. Using regression techniques, we determined the relationship of temperatures between Albuquerque and the experimental watershed.

Objective

The objective of this paper, then, is to show the precision with which temperature data may be projected from local records to predict the temperature at a remote site, in this instance San Luis watershed. From the calculations, we may predict the remote site temperatures for a point in time, a daily mean, or a monthly mean. We may set the limits, with 80 or 90 percent certainty, within which the true temperature lies.

Temperature Records

The San Luis watershed, elevation 6,540 feet, lies 60 air miles north-northwest of the Albuquerque airport, elevation 5,300 feet. The measurement site was a broad flood plain with a southerly slope of about 2 percent. Watershed rehabilitation and range production and utiliza-

[1] *Soil Scientist, Rocky Mountain Forest and Range Experiment Station, located at Albuquerque in cooperation with the University of New Mexico; Station's central headquarters maintained at Fort Collins in cooperation with Colorado State University. Research reported here was conducted in cooperation with the Bureau of Land Management, U. S. Department of the Interior.*

tion studies have been carried out at the San Luis site for several years. Air temperature was recorded continuously for 1 year at the experimental watershed with a type Vb mercury-filled temperature recorder. The stainless steel sensing bulb was suspended 1 foot above bare soil (fig. 1), shaded with a highly reflective sheet-metal cover about 6 inches above the bulb. Readings at 3-hour intervals were taken from the continuous-line charts at times corresponding with those reported by ESSA.[2] The march of temperatures at San Luis through a typical day in July and January is illustrated in figure 2.

Temperature at the Albuquerque airport was recorded from a sheltered hygrothermometer several hundred feet from any building and about 5 feet above ground level, over bare soil. The sensing unit was continuously ventilated by an aspirator. The site is a broad mesa with a westerly slope of about 1 percent.

Data Evaluation

Linear regressions of San Luis temperatures on Albuquerque airport temperatures were determined, and tolerance intervals for prediction of San Luis temperatures were calculated. Temperatures at 3-hour intervals, daily means, and monthly means at 3-hour intervals were evaluated. Serial correlation effects in the data were not calculated; considering the large number of observations, they were assumed to have no great effect on the results.

Regression Relations

Temperatures at the two locations may be related by the linear expression:

$$\hat{Y} = A + BX$$

where

Y = temperature at the remote site (San Luis),
X = temperature at the Albuquerque airport.

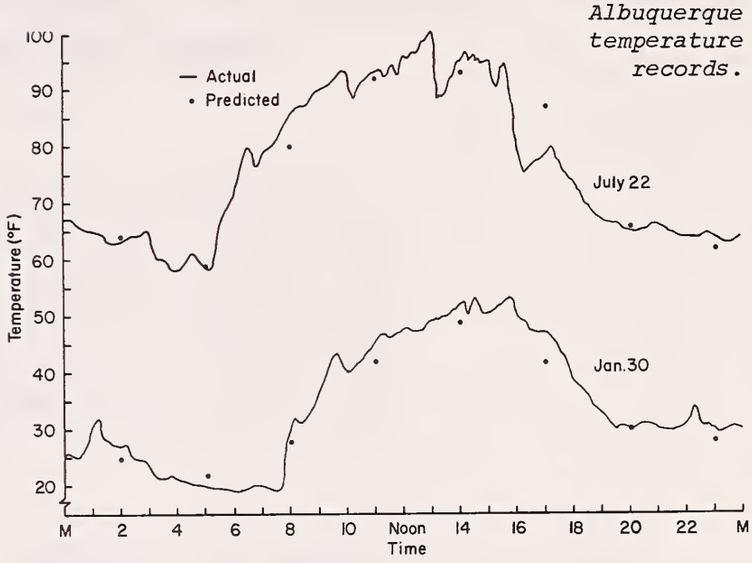
The correlation coefficients for Albuquerque versus San Luis temperatures ranged from 0.937 to 0.998 (table 1), indicating a very close relationship of temperatures between the two locations. Y intercept values (A) were all negative, indicating when Albuquerque temperatures were cold, San Luis temperatures were even colder.

Slopes of regression lines (B) exceeded 1 during daytime hours (0800 to 1700) and were less than 1 for nighttime (2000 to 0500). This relationship indicates that warming and cooling

[2] *Environmental Science Services Administration, Environmental Data Service. Local Climatological Data, Albuquerque, New Mexico, Sunport-Kirtland Air Force Base. 1967, 1968.*

Figure 1.--Temperature sensing bulb was suspended 1 foot above bare ground under highly reflective sheet metal cover. San Luis watershed III.

Figure 2.--Temperature record of a typical July and January day at San Luis. Dots are predicted temperatures from Albuquerque temperature records.



were both more intense at San Luis than at Albuquerque. That is, summer days tended to be warmer and nights cooler at San Luis than at Albuquerque.

Table 1.--Linear regression components[1] and correlation coefficients between air temperatures at San Luis watershed and Albuquerque airport, November 1967 - October 1968

Hour	Daily			Monthly mean		
	A	B	r	A	B	r
0200	-3.31	0.892	0.944	-3.82	0.901	0.996
0500	-2.14	.869	.937	-2.36	.874	.994
0800	-3.51	1.082	.963	-4.51	1.103	.997
1100	-3.89	1.093	.965	-5.55	1.123	.998
1400	-7.62	1.103	.966	-10.83	1.157	.996
1700	-11.38	1.061	.966	-14.20	1.104	.996
2000	-5.84	.944	.966	-7.82	.978	.994
2300	-4.17	.903	.957	-4.66	.913	.994
Mean	-6.22	1.020	.988	-7.08	1.033	.997

[1] $\hat{Y}=(A+BX)$ where $\hat{Y}$=temperature at San Luis, X=temperature at Albuquerque airport.

Tolerance Intervals

The confidence coefficient used in this paper is 95 percent, with an 80 or 90 percent tolerance. Eighty (or ninety) percent of observed temperatures will fall within the tolerance interval centered on the predicted value with a 95 percent confidence. The 80 percent tolerance interval is, of course, narrower than the 90 percent interval. The tolerance interval was used rather than the usual confidence interval because the prediction equation will presumably be used repeatedly and estimates will be used concurrently throughout the year. The tolerance intervals used apply to the whole regression line (Lieberman and Miller 1962) and are considerably wider than the usual confidence intervals for a single future observation.

Tolerance intervals are narrowest at the mean and widen at higher and lower values (table 2).

The curves delineating the tolerance interval were hyperbolic with respect to the predictive equation regression line (fig. 3). However, for estimating tolerance limits using the values in table 2, a straight line configuration was assumed between the limits at $\bar{x}$ and those at $\bar{x} \pm 10°$; and between limits at $\bar{x} \pm 10°$ and those at $\bar{x} \pm 40°$. This assumption resulted in an error of less than 0.1°.

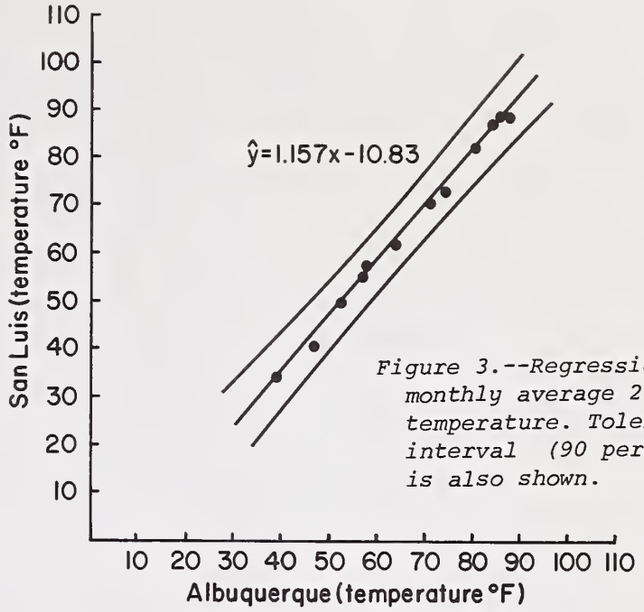


Figure 3.--Regression of monthly average 2 p.m. temperature. Tolerance interval (90 percent) is also shown.

Temperature Predictions

Daily

At a given hour of a day, the temperature at San Luis may be predicted within ±6.3° to

Table 2.--Tolerance intervals (°F.) of predicting daily and monthly 3-hour average temperatures at San Luis from temperatures at Albuquerque airport, November 1967-October 1968, 95 percent confidence

Hour	Mean daily temperatures ($\bar{x}$)		0.80 tolerance			0.90 tolerance		
	Albuquerque	San Luis	$\bar{x}$	$\bar{x} \pm 10°$	$\bar{x} \pm 40°$	$\bar{x}$	$\bar{x} \pm 10°$	$\bar{x} \pm 40°$
			- - - DAILY TEMPERATURES - - -					
0200	48.0	39.5	±6.9	±7.0	±8.2	±8.7	±8.8	±9.9
0500	45.2	37.1	6.8	6.9	8.1	8.6	8.7	9.9
0800	49.7	50.3	7.6	7.8	8.8	9.6	9.8	10.8
1100	60.1	61.8	7.7	7.8	8.8	9.7	9.8	10.8
1400	66.3	65.5	7.8	7.9	8.9	9.8	9.9	11.0
1700	65.3	57.9	7.5	7.6	8.6	9.5	9.6	10.6
2000	56.6	47.6	6.3	6.4	7.2	7.9	8.0	8.9
2300	51.8	42.6	6.3	6.4	7.4	7.9	8.0	9.0
Mean	55.5	50.4	3.8	3.9	4.4	4.8	4.9	5.4
			- - - MONTHLY TEMPERATURES - - -					
0200	48.0	39.4	±3.7	±4.0	±6.2	±4.5	±4.8	±6.9
0500	45.3	37.2	4.3	4.6	7.2	5.2	5.5	8.1
0800	49.7	50.3	5.0	5.2	7.5	6.0	6.2	8.6
1100	59.9	61.7	3.6	3.8	5.5	4.4	4.6	6.3
1400	66.3	65.9	5.5	6.9	8.5	6.6	7.0	9.6
1700	65.3	57.9	5.1	5.4	7.8	6.1	6.4	8.8
2000	56.7	47.6	5.5	6.9	8.6	6.6	7.0	9.7
2300	51.8	42.6	4.7	5.0	7.6	5.7	6.0	8.5
Mean	55.4	50.3						

±8.9°F., with 80 percent tolerance, depending on time of day and temperature. For example, assume the Albuquerque temperature at 2 p.m. (1400 hr.) is 75°F. Referring to table 1 for the equation values we have Y = 1.103 x 75 — 7.62 = 75.1°. From table 2, the tolerance interval corresponding to the daily 1400 hr. temperature about 10° from the mean is ±7.9°. Thus the temperature at San Luis is predicted to be (with 80 percent tolerance) between 67°F. and 83°F., or 75.1°F. ± 7.9°. The prediction is somewhat closer during night hours. For example, if the Albuquerque temperature at 11 p.m. (2300 hr.) were 40°F., the San Luis temperature would be predicted (based on the above formula and tables 1 and 2) to be between 25.6°F. and 38.4°F., or 32.0°F. ± 6.4°, with 80 percent tolerance.

The daily mean temperature can be predicted considerably more closely: ±3.8° to ±4.4°. For example, if the Albuquerque mean temperature for the day were 55°F., the San Luis temperature for the day would probably be between 46°F. and 54°F., or 50°F. ± 4°. Here the mean daily values from table 1 are used in the formula.

Monthly

If the July, 11 a.m. average temperature in Albuquerque were 84°F. (24° greater than the mean), the 80 percent tolerance interval (table 2) would be interpolated as ±4.6°. Referring to the monthly values in table 1, the San Luis temperature then would be predicted to be Y = 1.123 x 84 — 5.55 = 88.8° ± 4.6, with an 80 percent tolerance.

The monthly mean prediction for a given hour in the day (table 2) carries a confidence interval closely comparable to the daily mean confidence interval. The confidence intervals associated with the monthly mean at 0200 and 1100 hr. are about the same as for the daily mean. The intervals for other hours are slightly wider.

Discussion

The daily spread of temperatures at the San Luis watershed was generally greater than at Albuquerque. This difference can be partially explained on the basis of sensor position; the unit at Albuquerque was 5 feet above the ground whereas the unit at San Luis was only 1 foot above the ground. Diurnal temperature variations decrease with distance above the ground. Air temperature decreases with height during the day, and the gradient generally inverts at night (Geiger 1965, p. 83). Thornthwaite (1948-53) and Sinclair (1922) showed that air layers near the ground become isothermal almost simultaneously at all levels shortly after sunrise and again at about 1600 and 1700 hr.

The San Luis temperature did not equal or exceed Albuquerque until after 0800 hr. during most months, and except during July and August dropped below Albuquerque temperature before 1500 hr. The evening and nighttime temperatures were often as much as 10° cooler at San Luis than at Albuquerque. Although the influence of height of sensor was evident in the data, the temperature patterns did not follow a simple height difference relationship, but were influenced by other local factors.

Variable afternoon cloudiness, characteristic of both Albuquerque and San Luis, markedly affects air temperature. Because of this cloudiness, afternoon temperatures at San Luis cannot be predicted precisely during the summer monsoon season. On the other hand, storm patterns and frequency at San Luis are quite similar to those at Albuquerque during the fall, winter, and spring. The predictive equation could be strengthened by using more than 1 year's data, or by averaging several stations.

The equation components developed precisely fit the temperature relations between the two sites, as illustrated by the extremely high correlation coefficients. The precision and limits of predictions are clearly defined. Thus, within the limitations to the approach presented here, a complete year of temperature data from a remote site are sufficient for reasonably reliable prediction of temperature at that site.

Literature Cited

Geiger, Rudolf.
1965. The climate near the ground. Rev. ed. 611 p. Cambridge, Mass.: Harvard Univ. Press.

Lieberman, G. J., and R. G. Miller, Jr.
1962. Simultaneous tolerance intervals in regression. Appl. Math. and Stat. Lab., Stanford Univ. Tech. Rep. 59, 33 p. Stanford, Calif.

Sinclair, John G.
1922. Temperature of the soil and air in a desert. U. S. Mon. Weather Rev. 50: 142-144.

Thom, H. C. S.
1968. Standard deviation of monthly average temperature. ESSA Tech. Rep. EDS-3, PB 178309, 10 p., illus. Environ. Sci. Serv. Admin., Environmental Data Service, Silver Spring, Maryland.

Thornthwaite, C. W.
1948-53. Micrometeorology of the surface layer of the atmosphere. Pub. in Climatol. Vol. 1-5. Lab. Climatol., Seabrook and Centerton, N. J.